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Analytical Science of Plutonium

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This presentation is about the analytical science of plutonium[1] and techniques for its detection and measurement, both as an element and as individual isotopes. As a key component of the uranium fuel cycle, knowledge about the amount of plutonium and its isotopic composition is of paramount importance.

Plutonium analysis covers a mass concentration range of more than 10 orders of magnitude, from molar quantities in commercial reprocessing samples to micrometer-sized particles from environmental sampling. The analytical techniques described in this presentation cover this range.

Examples are the radiometric and mass spectrometric techniques used for process control of material flows, validation of neutronic calculation codes and for nuclear safeguards inspections at bulk handling fuel cycle facilities. These include X-ray densitometry and fluorescence for mass determinations, calorimetry for the analysis of solid samples, mass spectrometric methods for isotope determination at various levels of resolution and sensitivity, and the coupling of mass spectrometry with additional separation elements such as collision cells or capillary electrophoresis. Nuclear forensic investigations, which aim at the identification of plutonium at very low level require ultra-sensitive techniques such as accelerator mass spectrometry. Electron Microscopy and X-ray diffraction will be presented as tools for the study of surface properties.

Requirements for sensitivity and uncertainty vary widely, depending on the application. Manipulation of plutonium on the industrial scale requires detection techniques capable of measuring ~100 g/L mass concentrations of plutonium with uncertainties as low as 0.1% but does not necessarily require techniques with high sensitivities. The opposite is true for analyses at the environmental level, where the plutonium content typically varies from 10^8 to 10^9 atoms/g in solid material, and highest sensitivity is mandatory.

[1]Plutonium Handbook, Vol. 4, Ch. 24, Analytical Science of Plutonium, American Nuclear Society, 2nd Ed., 2019